Data review of $^6Li(p,p_0)^6Li$ cross-sections

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As a first step, the data sets already existing on IBANDL [1,2,5,6] were compared with the data in the original references and several inconsistencies were found.

Firstly, the reference in IBANDL data entry no. 1 (i.e. Bashkin and Richards) is wrong (actually, it refers to the work of Warters et al. on p+^{7}Li elastic scattering): the right one, S. Bashkin and H.T. Richards, Phys. Rev. 84 (1951) 1124, has been assigned to data entry no. 4, which is however incorrect since no such data point exists in the cited paper. Moreover, the original cross-section values from the work of Bashkin and Richards [1] were given in the laboratory frame of reference, while the data from IBANDL were calculated as if the original data were given in the centre-of-mass (thus the data resulted scaled down by a factor about 1.4); a shift of about +20 keV in the energy scale is evident too. The data available from the EXFOR nuclear database are consistent with the original ones [1], so in the following only the EXFOR data will be considered.

Then, IBANDL data entry no. 2 is wrong since no data point at 1.36 MeV and 90° scattering angle exists in the original work from Warters et al. (which, as stated above, refers only to p+^{7}Li elastic scattering). Again, IBANDL data entry no. 5 is wrong as well, since no data point at 1.36 MeV and 90° scattering angle exists in the original work from McCray [2].

IBANDL data entry no. 6 refers to a compilation of nuclear cross-sections for charged-particle-induced reactions on Li, Be and B from Kim et al. (correct reference: H.J. Kim, W.T. Milner and F.K. McGowan, Nuclear Data Sect. A, vol.1 no. 3-4 (1966) 211). Actually the data presented there are McCray's tabular cross-section values at a scattering angle of 90.75° in the centre-of-mass frame of reference (laboratory angle of 81.3°). Note that from McCray's original work [2] the correct angle should be 90.45°, corresponding to a laboratory angle of 81.0°. Moreover, these cross-section data are shown in [2] in two separate figures: Figure 3 displays them as ratio to Rutherford cross-section (together with other cross-section values measured at different scattering angles), while Figure 4 presents them as absolute values. Both data sets are available on EXFOR database. In the following figure a comparison between these three data sets (apparently referring to the same cross-section values) is shown.

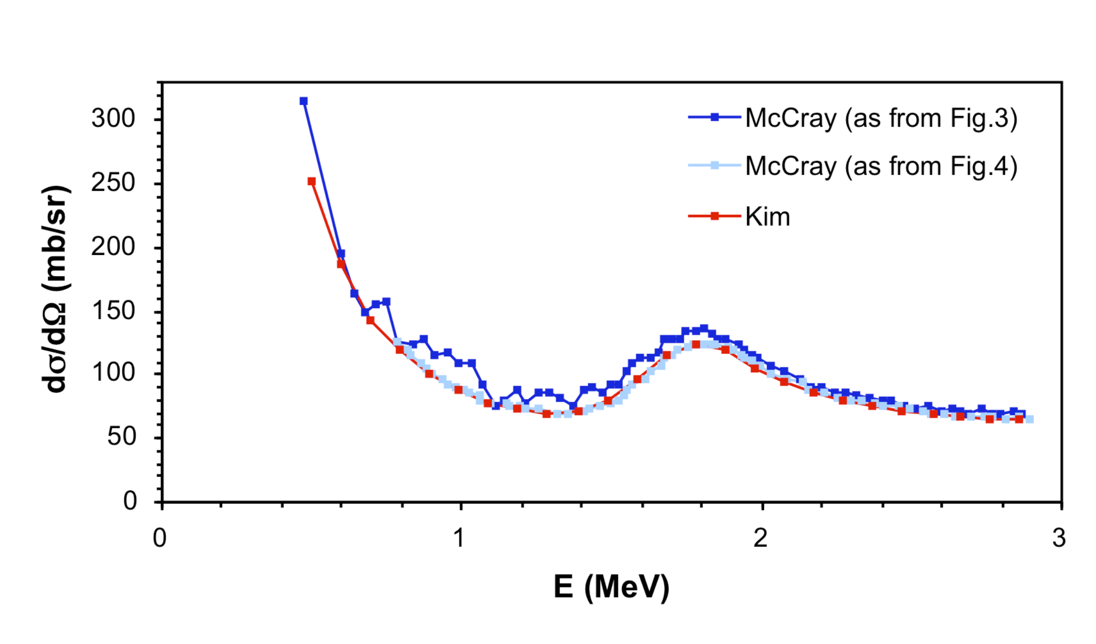

Figure 1: Cross-section values of proton elastic scattering on ^{6}Li versus proton energy at scattering angle of 81°. All the quantities are given in the laboratory frame of reference.

From the figure above, it is evident the discrepancy between McCray's data taken from the two different figures, which could be attributed to the difficulty of digitizing data from Figure 3 in [2]. The data appearing in Kim's compilation are in excellent agreement with McCray's ones from the original Figure 4. Note that IBANDL data as compared to tabulated data from Kim [5] have slightly different energy values (within ±5 keV) due to the rounding of digits and the cross-section values result scaled up by a factor 1.04, so in the following only the original data will be considered.

The second step was a thorough search in the literature and in nuclear databases for other available experimental data. Several data of interest for application in Ion Beam Analysis (i.e. for backscattering angles in the 90°-180° range) were retrieved [1-10]. All the relevant quantities were converted to the laboratory frame of reference when necessary. Table 1 lists the new data sets found in the literature; these new data will be uploaded into IBANDL if deemed appropriate.

Reference	Data source	θ_{lab}	E_p (MeV)	Target	Quoted uncertainties	Data presentation
[1]	EXFOR	164°	1.14–3.07	Natural Li metal evaporated onto thin Ni foil	20%	Tabular
[2]	EXFOR	118.2° 155.8°	0.4-2.9	^{6}Li metal samples (94.5% and 99.7% purity)	3%	Tabular
[3]	EXFOR	90°-160.0°	2.40-12.0	30-300 μg/cm^{2} ^{6}Li (enriched to 99%) evaporated on a thin C or Ni foil.	1-15% (statistics, background subtraction, normalization)	Tabular
[4]	EXFOR	100.3° 116.7° 140.6° 143.8° 166.4°	1.25-5.55	99.3% enriched ^{6}Li metal evaporation on a 1000 Å Ni foil	1.5% statistical, 1% background correction	Tabular
[5]	Original paper	81.0°	0.5-2.9	-	3%	Tabular
[6]	EXFOR	90°	1.36	0.03 to 0.1 mg/cm^{2} ^{6}LiF (95% enriched in ^{6}Li) evaporated on a C foil	15% statistical and systematic	Tabular
[7]	EXFOR	135° 150°	1.75-10.5	-	-	Tabular
[8]	Original paper	95.0°	6.868	Enriched ^{6}LiI (99.32%), natural LiF and LiI evaporated on a Formvar backing	5%	Tabular
[9]	EXFOR	90°-165° (5° steps)	1.3-10.1	LiF on Ni backing, Al-^{6}Li-C, C-^{6}Li-C (50 μg/cm^{2} ^{6}Li)	7.0%	Tabular
[10]	EXFOR	90°-160° (10° steps)	0.80-2.20 (0.1 MeV step)	C-^{6}LiF target (10 nm C and 100 nm ^{6}LiF)	0.2% statistical	Tabular

Table 1: Available data in the literature on $^{6}Li(p,p_0)^{6}Li$ cross-sections.

Note that an ambiguity arises from Haller's data: in Haller's original work [9] the cross-section values as a function of proton energy are shown in Figure 3, where the energy is indicated as "$E_{C.M.}$". In the paper the authors show also angular distribution data for several beam energies (see Figures 5 or 7 in the original reference): in this case, it is indicated in the text that the energy is expressed in the laboratory frame of reference. In the following figure it is shown the comparison between cross-section values for the same scattering angle (i.e. 160° in the laboratory) as obtained from the two figures, with the energy scale converted from centre-of-mass to laboratory system for data from Figure 3, together with the latter data without energy scale conversion. Data sources are EXFOR files.

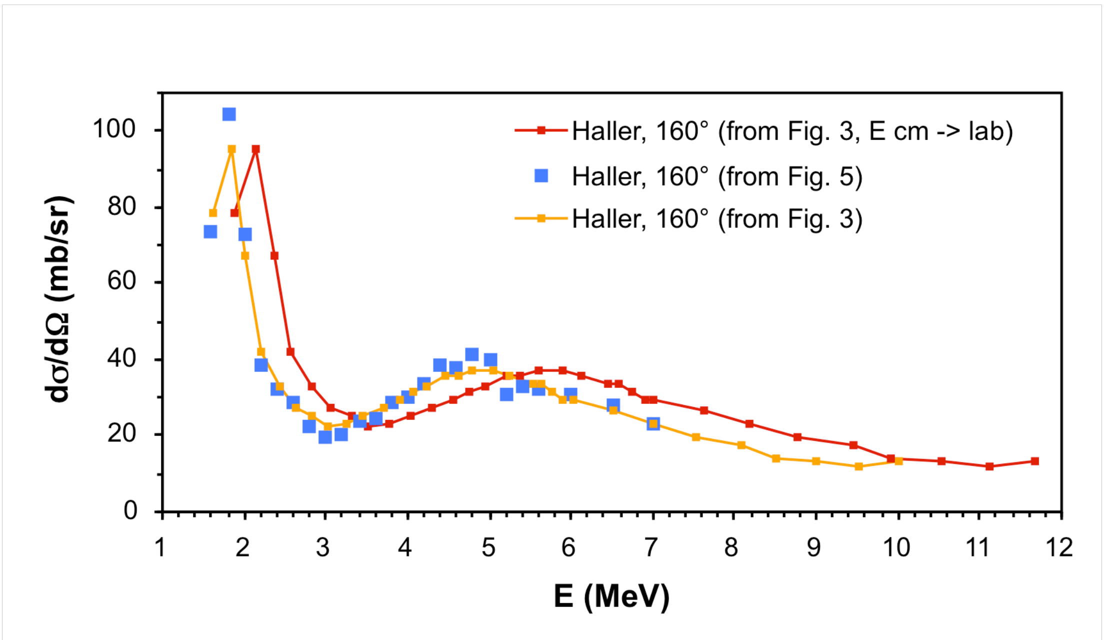

Figure 2: Cross-section values of proton elastic scattering on ^{6}Li versus proton energy at scattering angle of 160°. All the quantities are given in the laboratory frame of reference.

From the figure above, it is evident that the agreement is better if the energy is assumed as expressed in the laboratory frame of reference even for data from Figure 3. The same result holds true by comparing data obtained at other scattering angles. Thus, in the following Haller's data will be shown with proton energy not converted.

Figures 3-10 present in graphical form all the cross-sections listed in Table 1; data referring to similar scattering angles are shown together. In the graphs the proton energy and the differential cross-section are given in the laboratory frame of reference, with energy units in MeV and cross-section units in mbarn/sr.

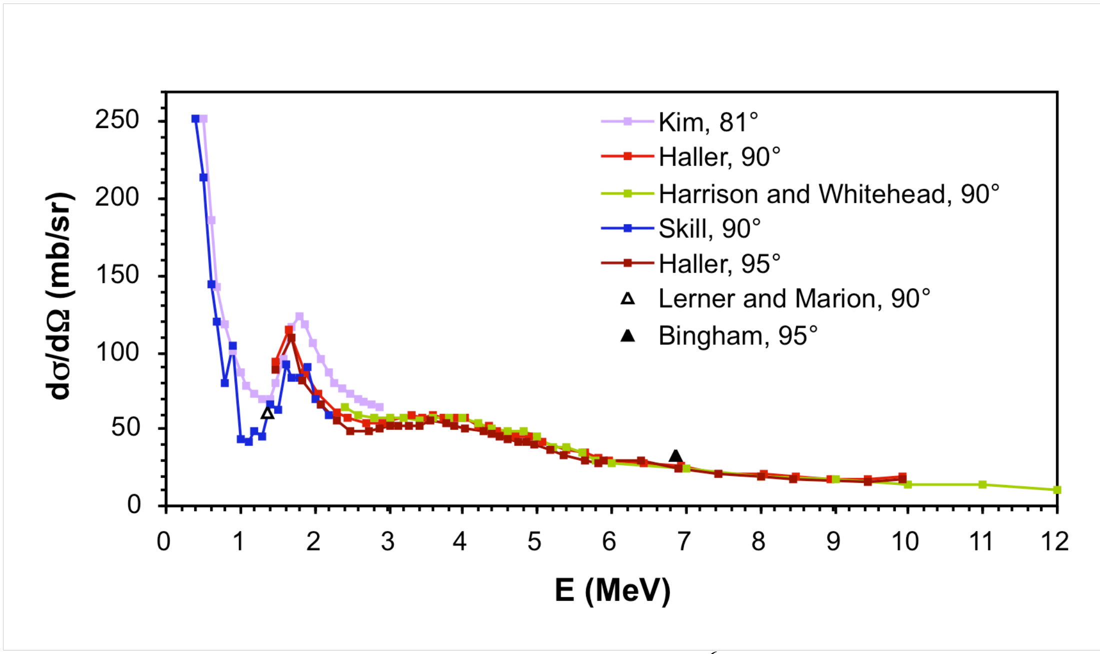

Figure 3: Cross-section values of proton elastic scattering on ^{6}Li versus proton energy at scattering angles in the 81°-95° range. All the quantities are given in the laboratory frame of reference.

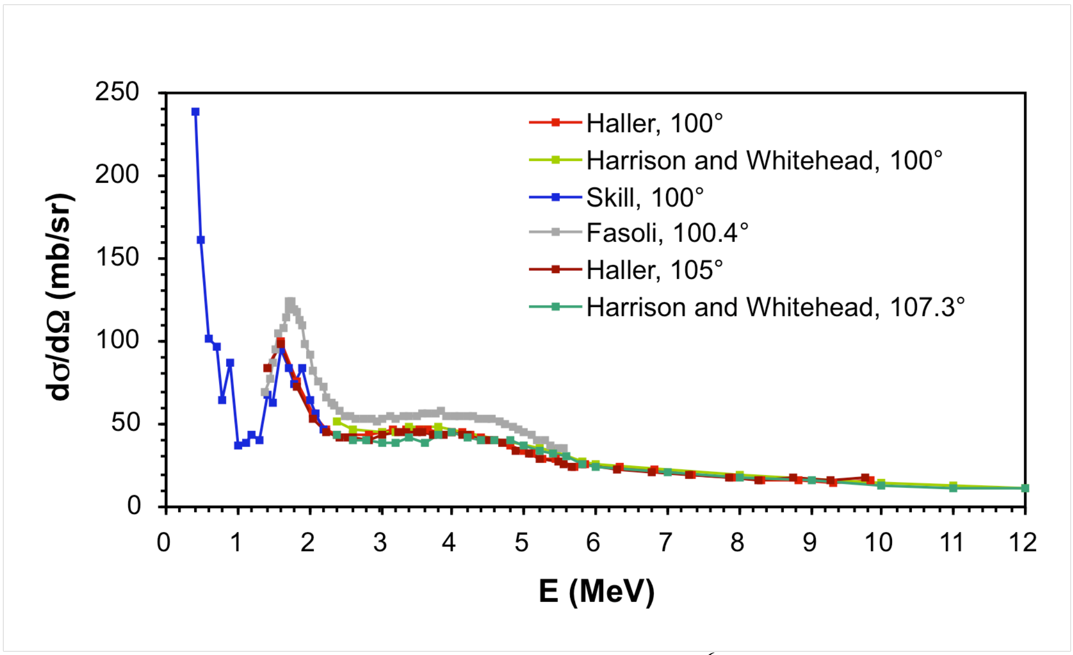

Figure 4: Cross-section values of proton elastic scattering on on ^{6}Li versus proton energy at scattering angles in the 100°-107° range. All the quantities are given in the laboratory frame of reference.

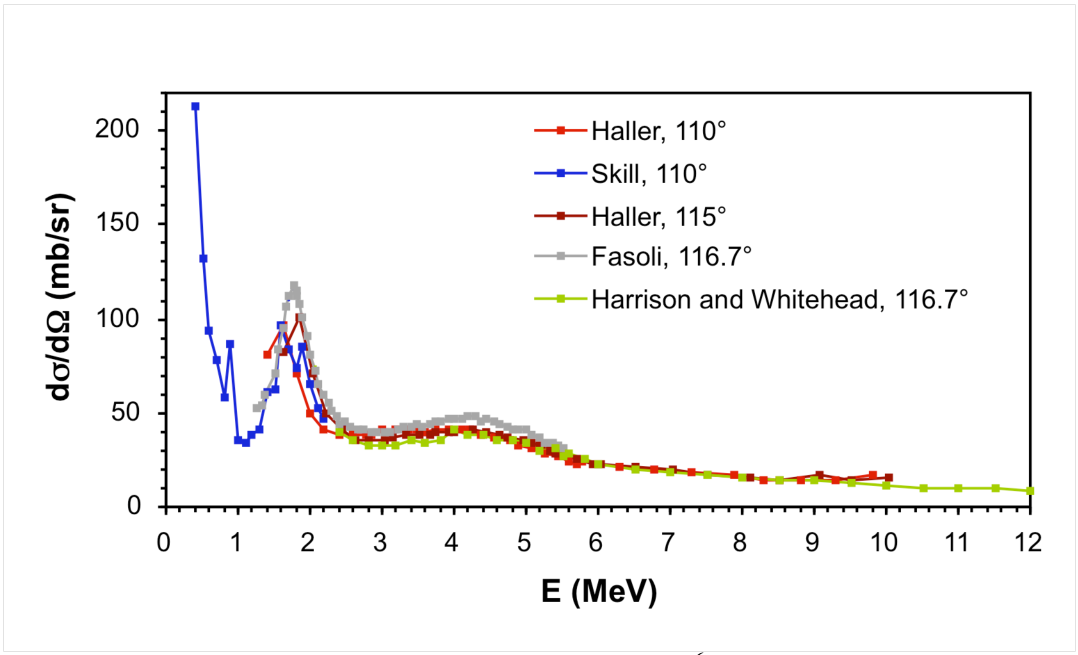

Figure 5: Cross-section values of proton elastic scattering on ^{6}Li versus proton energy at scattering angles in the 110°-117° range. All the quantities are given in the laboratory frame of reference.

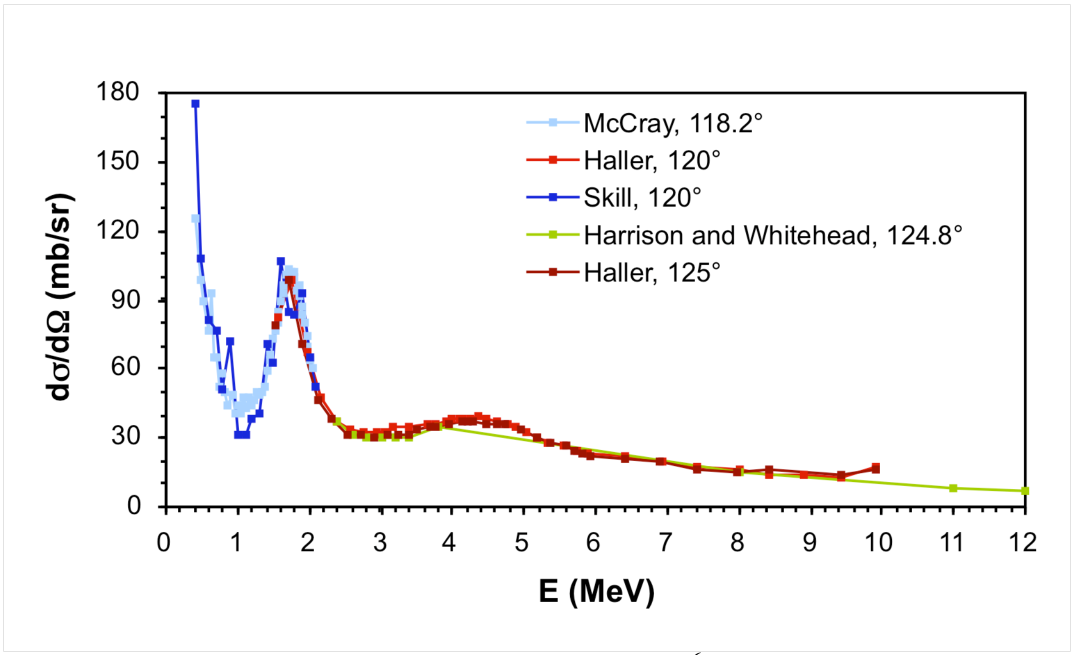

Figure 6: Cross-section values of proton elastic scattering on ^{6}Li versus proton energy at scattering angles in the 118°-125° range. All the quantities are given in the laboratory frame of reference.

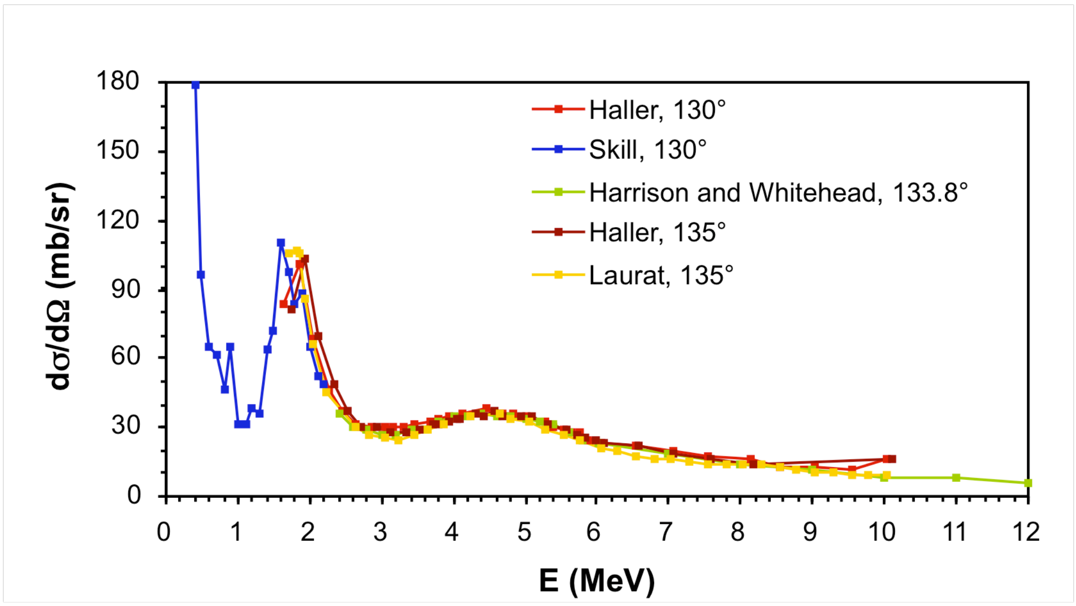

Figure 7: Cross-section values of proton elastic scattering on ^{6}Li versus proton energy at scattering angles in the 130°-135° range. All the quantities are given in the laboratory frame of reference.

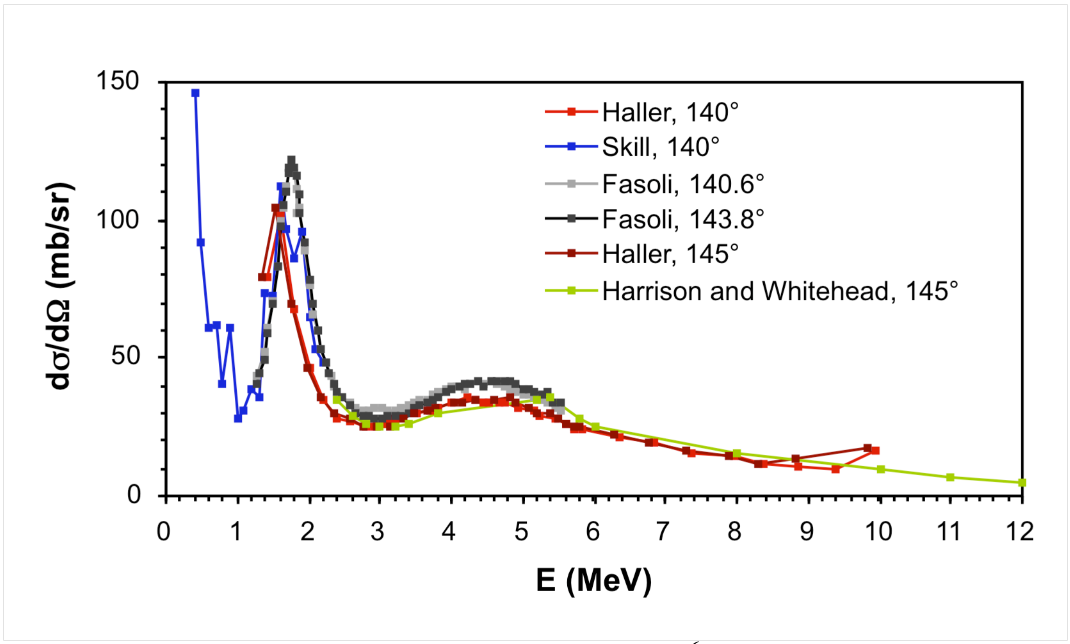

Figure 8: Cross-section values of proton elastic scattering on ^{6}Li versus proton energy at scattering angles in the 140°-145° range. All the quantities are given in the laboratory frame of reference.

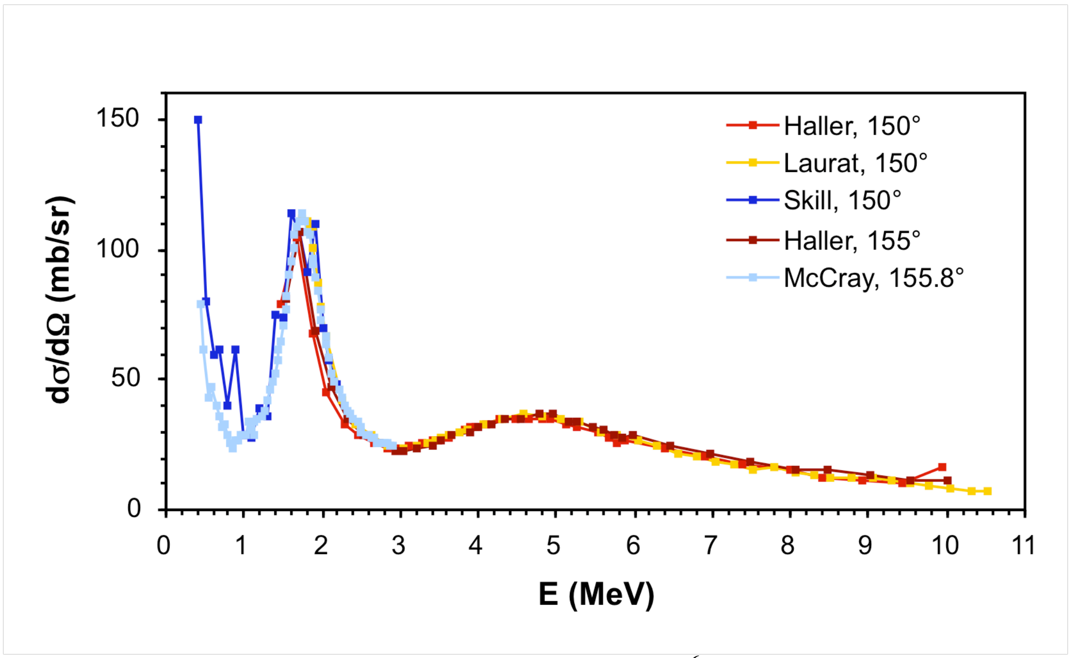

Figure 9: Cross-section values of proton elastic scattering on ^{6}Li versus proton energy at scattering angles in the 150°-156° range. All the quantities are given in the laboratory frame of reference.

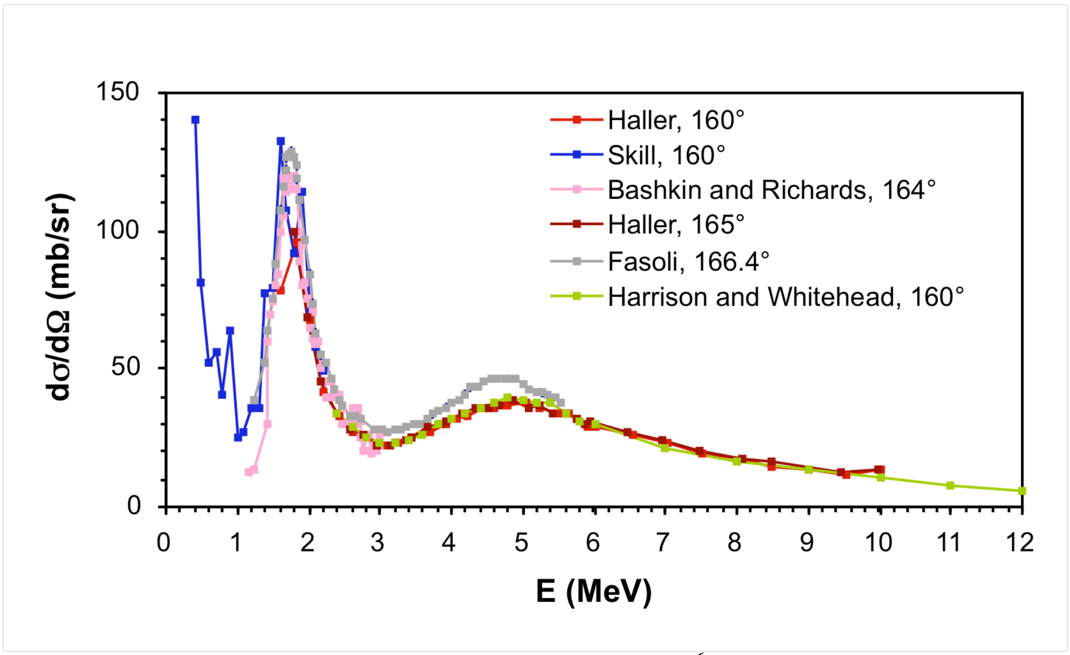

Figure 10: Cross-section values of proton elastic scattering on ^{6}Li versus proton energy at scattering angles in the 160°-166° range. All the quantities are given in the laboratory frame of reference.

In general, the agreement between the data – even those referring to slightly different scattering angles – is fairly good, except in a few cases.

In particular, data from Fasoli et al. [4] appear systematically higher (10-15%) than the other data at similar angles [1,7,9].

Data from Haller [9] show discrepancies with other data in correspondence of the 1.8 MeV resonance for some scattering angles, especially in the resonance position (e.g. see Figures 3, 4 and 8); moreover, note that due to the large energy step employed in the measurements (about 200 keV) the shape of the resonance is hardly reproduced at all. On the contrary, Haller's data are in agreement with other data [3,7] in the region around the broad structure at 4-5 MeV.

Data from Skill [10] are the only ones covering the low energy region (below 2 MeV) with high angular granularity, however they present fluctuating cross-section values that will produce corrugated spectra when implemented in simulation codes.

References

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[5] H.J. Kim et al., Nuclear Data A1 no. 3-4 (1966) 211

[6] G.M. Lerner and J.B. Marion, Nucl. Instr. Meth. 69 (1969) 115

[7] M. Laurat, Centre d`Etudes Nucleaires, Saclay Reports No.3727 (1969)

[8] H.G. Bingham et al., Nucl. Phys. A173 (1971) 265

[9] M. Haller et al., Nucl. Phys. A496 (1989) 189

[10] M. Skill et al., Nucl. Phys. A581 (1995) 93